Best Available Control Technology Determination for Control of Nitrogen Oxides for M.R. Young Station Units 1 and 2

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I. Introduction

In June of 2008, the North Dakota Department of Health (Department) provided for public comment a preliminary Best Available Control Technology (BACT) determination for the control of nitrogen oxides at both units of the M.R. Young Station. That preliminary determination indicated that selective catalytic reduction (including high dust SCR, low dust SCR and tailend SCR) was not technically feasible for the units at the M.R. Young Station. The preliminary determination was that BACT was represented by selective non-catalytic reduction (SNCR) plus advanced separated overfire air (ASOFA).

The Department received comments suggesting that all three types of SCR (HDSCR, LDSCR and TESCR) were technically feasible. Based on the comments, the Department reevaluated the technical feasibility of SCR (see Appendix A). Based on the information available at the time, the Department maintained its position that HDSCR was not technically feasible; however, the Department determined that LDSCR and TESCR were technically feasible. On June 15, 2009, the Department asked Minnkota Power Coop (Minnkota) to submit a cost estimate and complete the BACT analysis for LDSCR and TESCR. Minnkota, in submittals dated November 12, 2009, December 11, 2009 and February 11, 2010, provided the cost estimates and supporting documentation (see Appendix B).

This document provides the Department's evaluation of LDSCR and TESCR as a BACT control technology and provides a determination of BACT.

II. STEP 3: Rank Remaining Control Technologies by Control Effectiveness

A. Baseline Emissions

EPA's Draft New Source Review Workshop Manual (NSR Manual Section IV.D.2.b) states "The baseline emissions rate represents a realistic scenario of upper bound uncontrolled emissions for the source." The NSR Manual goes on to state "Estimating realistic upper-bound emissions does not mean one should assume the emissions represent the potential emissions." Also, the NSR Manual states "In addition, historic upper bound operating data, typical for the source or industry, may be used in defining baseline emissions in evaluating the cost effectiveness of a control option for a specific source." Minnkota has estimated their baseline emissions based on the following criteria:

Table 1
Predicted Operating Data

Operating Data	Unit 1	Unit 2
Baseline Emission Rate (lb/10^6 Btu/hr)	0.849	0.786
Heat Input (10^6 Btu/hr)	2744	4885
Availability	97.3%	93.9%
Baseline NO_x Emissions (tpy)	9,934	15,793

The Department evaluated the historical operating data from M.R. Young Station to determine if Minnkota's baseline emission rates were reasonable. Based on the maximum 2-year period (may be different for each parameter) in the last 5-years (2003-2007), the results are:

Table 2 **Historical Operating Data**		
Operating Data	**Unit 1**	**Unit 2**
Actual Emission Rate ($lb/10^6$ Btu/hr)	0.840	0.835
Heat Input (10^6 Btu/hr)	2,728	4,691
Availability[a]	96.4%	92.2%
Calculated Maximum Emissions (tpy)[b]	9,676	15,818
Historical NO_x Emissions (tpy)[c]	9,081	14,858

[a] Based on actual hours of operations.
[b] Based on actual emission rate ($lb/10^6$ Btu/hr), heat input (Btu/hr) and availability.
[c] Based on the average of the highest two years in the last five years.

Minnkota's calculated baseline emissions are somewhat higher than the historical emissions; however, it appears their calculated baseline emission rates are reasonable. Using historical baseline emissions would increase the cost effectiveness value for SCR and make it less attractive as a BACT control technology as shown in Table 5.

B. Control Alternatives Effectiveness

Table 3 **Emissions Reductions**				
			Controlled Emission Rate Annual Average	
Unit	**Technology[a]**	**Expected Efficiency (%)**	**$lb/10^6$ Btu**	**Tons/yr**
1	LDSCR + ASOFA (A)	93.8	0.053	586
1	LDSCR + ASOFA (B)	93.8	0.053	533
1	TESCR + ASOFA (A)	93.8	0.053	589
1	TESCR + ASOFA (B)	93.8	0.053	536
1	SNCR + ASOFA	58.1	0.355	4,025
1	Gas Reburn + ASOFA	56.0	0.374	4,275
1	Lignite Reburn + ASOFA	54.6	0.385	4,343
1	FLGR + ASOFA	45.9	0.460	5,260
1	ASOFA	39.5	0.513	5,874
1	Baseline	---	0.849	9,934
2	LDSCR + ASOFA (A)	93.8	0.049	931
2	LDSCR + ASOFA (B)	93.8	0.049	913
2	TESCR + ASOFA (A)	93.8	0.049	936
2	TESCR + ASOFA (B)	93.8	0.049	813

Table 3 Emissions Reductions				
			Controlled Emission Rate Annual Average	
Unit	Technology[a]	Expected Efficiency (%)	lb/10^6 Btu	Tons/yr
2	SNCR + ASOFA	58.0	0.330	6,421
2	Gas Reburn + ASOFA	55.4	0.350	6,882
2	Lignite Reburn + ASOFA	54.2	0.360	6,964
2	FLGR + ASOFA	45.0	0.432	8,490
2	ASOFA	37.7	0.489	9,621
2	Baseline	---	0.786	15,793

[a] Scenario (A) based on a catalyst replacement schedule of 16,000 hours. Scenario (B) based on catalyst replacement during scheduled outages. For Unit 1 this is every 4 months and for Unit 2 this is every 3 months.

III. STEP 4: Evaluate Most Effective Controls and Document Results

A. Cost/Economic Analysis

The NSR Manual (Section IV.D.2.a) states "Total cost estimates of options developed for BACT analyses should be on the order of plus or minus 30 percent accuracy." Minnkota has developed costs estimates that are site specific. The cost estimates are based on information supplied by design engineers and vendors. The estimates appear to be within ± 30% for the design presented.

Minnkota has supplied four different cost estimates for LDSCR and TESCR. Two cost estimates are based on each unit operating as a stand-alone facility and two estimates are based on Unit 1 and Unit 2 having shared facilities. The other cost parameter that varies is the catalyst replacement schedule. Minnkota included two schedules, every 16,000 hours or every scheduled shutdown of the unit (3-4 months depending on the unit). The 3-4 months (approximately 2,200 – 2,900 hours) catalyst replacement would represent a catalyst life which the Department considers to be unsuccessful application of SCR technology and thus SCR would be technically infeasible. However, the lack of a vendor guarantee and statements made by the vendors (as discussed in Step 5) provides some justification for submitting such an estimate. The Department has included both estimates in this analysis.

Minnkota believes the BACT determination should be based on the estimate provided for the stand-alone facilities. Their reasoning is that BACT, by definition, is determined on a case-by-case basis (i.e. seperate for each unit). Paragraph 65 of the Consent Decree requires a BACT analysis for <u>each</u> unit and Minnkota has supplied a separate analysis for each unit.

Unit 1 and Unit 2 at the M.R. Young Station are both cyclone-fired units burning lignite from the Center Mine. The likely outcome is that BACT will be the same for both units. Therefore, the design of the systems would logically share facilities such as the natural gas pipeline for reheat fuel and urea storage facilities. This would be the least expensive system to build and would better represent the true cost of the systems. Therefore, the Department has only included in its analysis the shared facilities cost estimate.

Table 4
Costs
Minnkota's Baseline Emissions

Unit	Technology	NO_x Reduction (tons/yr)	Levelized Annualized Cost ($)	Cost Effectiveness ($/ton)	Incremental Cost Effectiveness ($/ton)
1	LDSCR + ASOFA (A)	9,348	33,526,000	3,586	7,576[a]
1	LDSCR + ASOFA (B)	9,401	45,244,000	4,813	10,817[a]
1	TESCR + ASOFA (A)	9,345	39,307,000	4,206	9,265[a]
1	TESCR + ASOFA (B)	9,398	50,937,000	5,420	12,458[a]
1	SNCR +ASOFA	5,909	7,472,000	1,265	2,697[b]
1	Gas Reburn + ASOFA[c]	5,659	37,334,000	6,597	---
1	Lignite Reburn + ASOFA[c]	5,591	11,383,000	2,037	---
1	FLGR + ASOFA[c]	4,674	16,990,000	3,635	---
1	ASOFA	4,060	2,489.000	613	---
2	LDSCR + ASOFA (A)	14,862	57,351,000	3,859	8,330[a]
2	LDSCR + ASOFA (B)	14,980	86,542,000	5,777	13,360[a]
2	TESCR + ASOFA (A)	14,875	66,506,000	4,476	10,007[a]
2	TESCR + ASOFA (B)	14,980	96,268,000	6,426	15,095[a]
2	SNCR +ASOFA	9,372	11,618,000	1,240	2,263[b]
2	Gas Reburn + ASOFA[c]	8,910	63,982,000	7,181	---
2	Lignite Reburn + ASOFA[c]	8,829	19,475,000	2,206	---
2	FLGR + ASOFA[c]	7,303	29,317,000	4,014	---
2	ASOFA	6,172	4,376,000	709	

[a] Incremental cost between given technology and SNCR + ASOFA.
[b] Incremental cost between SNCR + ASOFA and ASOFA.
[c] Inferior options.

Table 5
Costs
Historical Baseline Emissions

Unit	Technology	NO_x Reduction (tons/yr)	Levelized Annualized Cost ($)	Cost Effectiveness ($/ton)	Incremental Cost Effectiveness ($/ton)
1	LDSCR + ASOFA (A)	8,518	33,526,000	3,936	8,036[a]
1	LDSCR + ASOFA (B)	8,518	45,244,000	5,312	11,645[a]
1	TESCR + ASOFA (A)	8,518	39,307,000	4,615	9,820[a]
1	TESCR + ASOFA (B)	8,518	50,937,000	5,980	13,407[a]
1	SNCR + ASOFA	5,276	7,472,000	1,416	2,950[b]
1	Gas Reburn + ASOFA[c]	5,085	37,334,000	7,342	
1	Lignite Reburn + ASOFA[c]	4,958	11,383,000	2,295	

Table 5 Costs Historical Baseline Emissions					
Unit	**Technology**	**NO_x Reduction (tons/yr)**	**Levelized Annualized Cost ($)**	**Cost Effectiveness ($/ton)**	**Incremental Cost Effectiveness ($/ton)**
1	FLGR + ASOFA[c]	4,168	16,990,000	4,076	
1	ASOFA	3,587	2,489,000	694	
2	LDSCR + ASOFA (A)	13,937	57,351,000	4,115	8,598[a]
2	LDSCR + ASOFA (B)	13,937	86,542,000	6,210	14,086[a]
2	TESCR + ASOFA (A)	13,937	66,506,000	4,772	10,319[a]
2	TESCR + ASOFA (B)	13,937	96,268,000	6,907	15,915[a]
2	SNCR + ASOFA	8,618	11,618,000	1,348	2,400[b]
2	Gas Reburn + ASOFA[c]	8,231	63,982,000	7,773	
2	Lignite Reburn + ASOFA[c]	8,053	19,475,000	2,418	
2	FLGR + ASOFA[c]	6,686	29,317,000	4,385	
2	ASOFA	5,601	43,760,007	781	

[a] Incremental cost between given technology and SNCR + ASOFA.
[b] Incremental cost between SNCR + ASOFA and ASOFA.
[c] Inferior options.

Because of lack of a vendor guarantee without pilot scale testing and statements made by the vendors (see Step 5), 16,000 hours between catalyst change out may not be possible. The following represents an average for the two catalyst changeout scenarios presented by Minnkota.

Table 6 Average Costs Minnkota's Baseline Emissions					
Unit	**Technology**	**NO_x Reduction**	**Levelized Annual Cost[b]**	**Cost Effectiveness ($/ton)**	**Incremental Cost Effectiveness ($/ton)**
1	LDSCR + ASOFA	9,375	39,385,000	4,201	9,207[a]
1	TESCR + ASOFA	9,372	45,122,000	4,815	10,872[a]
1	SNCR + ASOFA	5,909	7,472,000	1,265	
2	LDSCR + ASOFA	14,921	71,947,000	4,822	10,872[a]
2	TESCR + ASOFA	14,919	81,387,000	5,455	12,578[a]
2	SNCR + ASOFA	9,372	11,618,000	1,240	

[a] Incremental cost of selected technology versus SNCR + ASOFA.
[b] Average cost for the two scenarios.

B. Energy Impact Analysis

Minnkota has evaluated the energy impacts associated with each control option. TESCR would have the highest power usage followed closely by LDSCR. The power usage by TESCR is approximately 100 times that of SNCR. Although there is a large discrepancy in the power usage, the amount of power used, by itself, would not preclude the use of LDSCR or TESCR. However, it is a consideration in determining BACT for the source.

C. Environmental Impacts

The installation of either SCR or SNCR at M.R. Young will increase ammonia emissions to the atmosphere due to ammonia slip. However, it is expected that the ammonia slip can be limited to 2-5 ppmvd at 3% O_2. No adverse environmental impacts are expected from this amount of ammonia slip. Use of a SCR catalyst may lead to increased formation of ammonium bisulfate and/or ammonium sulfate. The Department believes these air contaminants will not be emitted in a quantity that adversely affect the environment. Catalyst disposal will be another environmental issue for SCR. The relatively small volume of catalyst that must be disposed will not present any significant effects.

The increased power usage by LDSCR and TESCR will result in additional air pollutants being emitted to the atmosphere. The increase in CO_2 emissions for SCR versus SNCR are as follows:

Table 7
CO_2 Increase

Unit	Control Alternative	CO_2 Increase (Tons/yr)
1	TESCR (A)	78,300
1	TESCR (B)	71,500
1	LDSCR (A)	64,700
1	LDSCR (B)	58,800
2	TESCR (A)	114,600
2	TESCR (B)	99,400
2	LDSCR (A)	94,900
2	LDSCR (B)	82,800

Based on the information presented, there appears to be no environmental impacts that would preclude the selection of SCR or SNCR as BACT. However, the environmental impacts are considered in the BACT selection process.

D. Consideration of Emissions of Toxic or Hazardous Air Pollutants

As discussed in the previous section, the Department believes any additional emissions of air contaminants, including toxic or hazardous contaminants, will not have a significant adverse effect on the public or the environment.

IV. STEP 5: Select BACT

Minnkota maintains that SCR, no matter where it is located (i.e. HDSCR, LDSCR or TESCR), is not technically feasible for the units at the M.R. Young Station. Based on the information provided through June 2009, the Department made a determination that HDSCR was not technically feasible; however, LDSCR and TESCR were technically feasible. This determination was based, in part, on assurances by SCR and catalyst vendors that a catalyst life guarantee could be obtained without pilot-scale testing. Two of these vendors were CERAM Environmental, Inc. (CERAM) and Haldor Topsoe, Inc. Despite their concerns about technical feasibility, Minnkota worked with CERAM and Haldor Topsoe to develop a cost estimate for both LDSCR and TESCR. As part of the process to develop the cost estimate, Minnkota supplied both vendors with detailed information about the flue gas characteristics of the M.R. Young Station (see Microbeam Technologies report, July 1, 2009). Based on their review of the data, both vendors have refused to provide a catalyst life guarantee for either LDSCR or TESCR without pilot-scale testing. This is in direct contrast to earlier statements by both companies.

In their proposals to Minnkota, both companies have made statements that bring into question the technical feasibility of both LDSCR and TESCR (see Appendix D). CERAM has stated that it is unaware of any SCR application experience in the industry with the level and form of sodium in the M. R. Young Station ash. Haldor Topsoe has stated that the potential exists that physical deactivation due to catalyst blinding and plugging could be severe enough to make SCR a non-viable option for controlling NO_x emissions.

Several times statements have been made by commenter's that sodium and potassium aerosols are not a catalyst poison unless the temperature of the reactor is below the dew point (i.e. moisture carries the sodium and potassium to the active sites). CERAM has stated in their proposal that small aerosol particles can penetrate and neutralize active catalyst sites <u>even in dry conditions</u>. In addition, CERAM states that catalyst installed even in low dust and tailend locations are poisoned from the exposure to the flue gas and the high levels of phosphorous, sodium and potassium found in the mineral analyses at M.R. Young Station will increase deactivation rates. This is consistent with the findings of Kling, et.al.[1] and Zheng, et.al.[2]

EPA's New Source Review Workshop Manual (Section IV.B) states "A control technique is considered available, within the context presented above, if it has reached the licensing and commercial sales stage of development. A source would not be required to experience extended time delays or resource penalties to allow research to be conducted on a new technique. Neither is it expected that an applicant would be required to experience extended trials to learn how to apply a technology to a totally new and dissimilar source type. Consequently, technologies in the pilot-scale testing states of development would not be considered available for BACT review." CERAM's statement that they are unaware of any SCR application experience in the industry with the level and form of sodium in the ash at M.R. Young Station indicates this is a new and dissimilar source type based on the flue gas characteristics.

Vendors' statements that they will not provide a catalyst guarantee without pilot-scale testing indicate SCR (HDSCR, LDSCR or TESCR) for use on a boiler firing North Dakota lignite could be considered in the pilot-scale testing stages of development. The lack of vendor guarantees and statements from the vendors regarding physical deactivation (plugging and masking) indicate successful application of SCR technology is not assured.

The NSR Manual (Section IV.D.2.c) states "…if the cost of reducing emissions with the top control alternative, expressed in dollars per ton, is on the same order as the cost previously borne by other sources of the same type in applying that control alternative, the alternative should initially be considered economically achievable, and therefore acceptable as BACT." The Department has gathered information from recent BACT determinations that required SCR to determine the estimated cost at these sources. The results in Table 8 show a pattern of significantly higher costs at M.R. Young Station than at other recently permitted sources. Unfortunately, SCR is the most efficient NO_x removal technology. Many BACT analyses do not contain cost data because it is the top technology. If the top control technology is selected as BACT, a cost estimate is not required (as allowed by the NSR Manual Section III.C). Where a cost for SCR was provided and SCR was selected at BACT, the costs were probably not verified by the reviewing agency. This leads to uncertainty regarding the actual cost effectiveness for sources where SCR was selected as BACT.

Table 8
BACT Costs

Source	Cost Effectiveness ($/ton)	Estimated Efficiency
M.R. Young Unit 1	4,201	93.8
M.R. Young Unit 2	4,822	93.8
Dry Fork	1,511	83
Wygen 3[a]	4,037	89
Norborne	2,600	85%
Turk	2,439	74%
TS Power Plant	2,047	66%

[a] 110 MWe Plant – LNB + OFA + SCR

In order to gather more data about the cost of SCR, the Department reviewed the Best Available Retrofit Technology (BART) analyses that were submitted to surrounding states. The results in Table 9 show a much higher expected annualized cost ($/kw) and cost effectiveness at M.R. Young Station than sources subject to BART requirements.

Table 9
BART Costs

Source	NO_x Controls	Expected Efficiency (%)	Annualized Cost ($/kw)	Cost Effectiveness ($/ton)[a]
M.R. Young 1[d]	ASOFA + SCR	93.8	153.25	4,201
M.R. Young 2[d]	ASOFA + SCR	93.8	150.82	4,822
Colstrip 1 & 2	LNB + SCR	57	23.74	2,272
Dave Johnson 3	LNB + OFA+ SCR	90	42.17	1,401
Laramie River 1	SCR	74	23.22	2,828
Laramie River 2	SCR	74	24.07	2,844

Table 9 BART Costs				
Source	**NO_x Controls**	**Expected Efficiency (%)**	**Annualized Cost ($/kw)**	**Cost Effectiveness ($/ton)[a]**
Laramie River 3	SCR	74	24.07	2,772
Nebraska City Station #1	LNB + OFA + SCR	86	32.77	2,633
PGE Boardman[b]	LBN + OFA + SCR	84	47.81	3,096
Sherco #1[c]	CC + LNB + SOFA + SCR	76	25.82	2,500
Sherco #2[c]	CC + SCR	60	21.99	4,600
J.E. Corette	SCR	42-54	23.52	4,354
Big Stone	SCR + SOFA	80-90	27.81	825
Boswell Energy Center #3	LNB + OFA + SCR	81	33.33	3,201
GGS 1 & 2	LBN + OFA + SCR	82	41.94	2,297
Healy	SCR	---	35.90	3,374
Jim Bridger 1	LNB + OFA+ SCR	84	29.43	1,736

[a] Consultant's estimate except as noted.
[b] ERG, working for the Oregon DEQ, estimated the capital cost to be 27% less than the PGE consultant. The ERG estimate would yield a cost of approximately $39.78/kw and $2,600/ton.
[c] Baseline emission rate is 0.20 lb/10^6 Btu. CC = combustion optimization system.
[d] Based on LDSCR and average of Scenarios A and B.

The cost effectiveness in Tables 8 and 9 can be misleading since the calculated values are dependent on the projected efficiency of the NO_x combustion controls and add on controls. Minnkota has used the highest efficiency (93.8%) of any analysis reviewed. This leads to a lower cost effectiveness. As noted in the NSR Manual (Section IV.D.2.b), unrealistically low estimates of the emission reduction potential of a certain technology could result in inflated cost effectiveness figures.

The NSR (Section IV.D) also states "The determination that a control alternative is inappropriate involves a demonstration that circumstances exist at the source which distinguish it from other sources where the control alternative may have been required previously, or that argue against the transfer of technology or application of new technology". Minnkota has claimed that the flue gas characteristics, even for SCR in a low dust or tailend position, are different from any other facility were SCR has been applied. This claim has been corroborated by CERAM which indicated they were unaware of any SCR experience with a source that has similar flue gas characteristics. The lack of a vendor guarantees and Haldor Topsoe's statement that LDSCR and TESCR might not be a viable option for NO_x control at M.R. Young appears to distinguish M.R. Young Station from other sources where SCR has been applied.

The average cost effectiveness (excluding M.R. Young Station) from Table 8 is $2,527/ton and $2,664/ton from Table 9. The expected cost effectiveness at M.R. Young is significantly higher than these values (54% - 91%). The cost effectiveness of SCR at M.R. Young Station is higher than any other facility in Table 7. The cost effectiveness at M.R. Young Station is higher than any BART facility in Table 8 except Sherco No. 2 and J.E. Coretta. However, the cost effectiveness at Sherco No. 2 was based on 60% removal efficiency and 42-54% at Corette. Had 93.8% removal efficiency been used, the cost effectiveness would be substantially less than at M.R. Young Station.

The Department has also considered the incremental cost of SCR (TESCR or LDSCR) versus SNCR. The incremental cost varies from $7,576/ton to $10,817/ton for LDSCR at Unit 1 based on Minnkota's calculation and $8,330/ton to $13,360/ton at Unit 2. The Department considers this incremental cost to be very high. The State of Pennsylvania rejected wet scrubbing at the River Hill Power company facility which had an incremental cost of $5,000/ton. The State of Georgia rejected wet scrubbing at the Long Leaf Energy Station which had an incremental cost of $8,964/ton. The State of Nebraska rejected SNCR achieving 0.05 lb/MMBtu based on an incremental cost of $5,600/ton at an ADM facility in Columbus, Nebraska and limestone injection with an incremental cost of $6,700/ton. The State of Nebraska also rejected dry scrubbing at a Cargill, Inc. facility in Blair, Nebraska which had an incremental cost of $5,900/ton. The State of Texas rejected wet limestone scrubbing at the Sandy Creek Station which had an incremental cost of $5,000/ton. EPA, Region 8 rejected limestone injection and a wet scrubber at the Deseret Power Plant based on an incremental cost of $10,540/ton. The State of Wyoming rejected an SCR operating at 0.043 lb/10^6 Btu at the Dry Fork Plant based on an incremental cost of $10,300/ton.

In summary, the Department has significant concerns whether LDSCR and TESCR are technically feasible for the M.R. Young Station. Selection of SCR as BACT will increase CO_2 emissions up to 193,000 tons per year (Units 1 and 2 combined) over SNCR. The expected cost effectiveness is higher than other plants where SCR has been applied as BACT. It is significantly higher than the average cost effectiveness values for sources subject to BART. Table 8 shows the disproportional annualized costs that Minnkota would have to bear. The incremental cost of SCR versus SNCR is very high. Incremental costs that are less than at M.R. Young Station have lead to rejection of BACT alternatives by other states and EPA.

The Department has determined that HDSCR is not technically feasible. Based on concerns regarding technical feasibility of LDSCR and TESCR, the high cost effectiveness, the high incremental cost and increased greenhouse gas emissions, the Department has determined that neither LDSCR nor TESCR represent BACT at M.R. Young Station. The Department affirms its June 2008 proposal that BACT for both units is represented by SNCR + ASOFA.

References

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3. EPA, 1990 New Source Review Workshop Manual, Prevention of Significant Deterioration and Nonattainment Area Permitting, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711.